April 6, 2001
HETA 2001-0100

Mr. Bob Clark
Vice President
Seven Crown Resorts
322 Lakeshore Road
Boulder City, Nevada 89005

Dear Mr. Clark:

On December 8, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request from management officials of Seven Crown Resorts to evaluate carbon monoxide (CO) concentrations associated with the operation of houseboats on Lake Mead. On January 24 - 25, 2001, NIOSH investigators conducted a site visit at Lake Mead to investigate CO concentrations on houseboats located at Echo Bay Marina, Nevada. This letter describes our evaluation methods, findings, and conclusions.

Background

Previous investigations were performed by NIOSH industrial hygienists and representatives from several agencies in September 2000 and October 2000 in response to CO related poisonings and deaths on houseboats at Lake Powell, Arizona. These investigations characterized the circumstances of boat related CO poisonings through review of emergency medical service (EMS) transport records, and measured hazardous CO concentrations on houseboats.[1, 2] Incident reports provided by the National Park Service revealed 9 known boat-related CO poisoning deaths on Lake Powell since 1994. Some of these incidents involved multiple poisonings in addition to the deaths reported (total of 15 people poisoned in the 8 incidents involving fatalities). Information regarding the fatalities is addressed in a previous report.[1] An additional evaluation conducted in October 2000 at Lake Cumberland, Kentucky also revealed hazardous CO concentrations around the swim platform on houseboats with gasoline powered generators/motors.[3]

Some of the severely hazardous situations identified during the September and October 2000 evaluations at Lake Powell and Lake Cumberland included:

- The open space under the swim platform could be lethal under certain circumstances (i.e.,

generator/motor exhaust discharging into this area) on some houseboats.

- Some CO concentrations above and around the swim platform were at or above the immediately dangerous to life and health (IDLH) level (greater than 1,200 parts of CO per million parts of air [ppm]).
- At Lake Powell, measurements of personal CO exposure during boat maintenance activities indicated that employees may be exposed to hazardous concentrations of CO. (Personal monitoring on workers at Lake Cumberland was not conducted)

Please refer to Attachments 1 and 2 for discussions of health effects of CO exposure and relevant evaluation criteria.

Methods and Materials

During our investigation at Lake Mead, CO was measured in the area on the back of houseboats when only the generator was in operation, and when the generator and boat engines were operating simultaneously.

The environment near the generator exhaust discharge was characterized using a KAL Equip Model 5000 Four Gas Emissions Analyzer (KAL Equip, Cleveland, Ohio). This analyzer measures CO, carbon dioxide (CO_2), hydrocarbons, and oxygen (O_2). Carbon monoxide and O_2 measurements are expressed as percentages. (One percent of contaminant is equivalent to 10,000 ppm.)

Carbon monoxide concentrations were measured on the back of the houseboats using ToxiUltra Atmospheric Monitors (Biometrics, Inc., Middletown, Connecticut) with CO sensors. All ToxiUltra CO monitors were calibrated before and after each use according to the manufacturer's recommendations. These monitors are direct-reading instruments with data logging capabilities. The instruments were operated in the passive diffusion mode, with a 30 second sampling interval. The instruments have a nominal range from 0 ppm to 500 ppm with the highest accurate instantaneous reading of 1000 ppm. Figure 1 illustrates a typical houseboat (seen during previous CO evaluations) and where ToxiUltra CO monitors were placed. Some of the locations varied on different houseboats depending on the swim deck and swim platform designs. Echo Bay Marina houseboats were pontoon houseboats and did not have slides located on the back deck.

Carbon monoxide measurements were also made with detector tubes (Drager CO, CH 29901– range 0.3% [3,000 ppm] to 7% [70,000 ppm], and Drager CO, CH 25601-range 100 - 700 ppm) in the areas near the exhaust and around the swim deck. The detector tubes are used by drawing air through the tube with a bellows–type pump. The resulting length of the stain in the tube (produced by a chemical reaction with the sorbent) is proportional to the concentration of the air contaminant.

"Grab" samples were collected using Mine Safety and Health Administration (MSHA) 50–milliliters

(mL) glass evacuated containers. These samples were collected by snapping open the top of the evacuated glass container and allowing the air to enter. The containers were sealed with wax–impregnated MSHA caps. The samples were then sent by overnight delivery to the MSHA laboratory in Pittsburgh, Pennsylvania where they were analyzed for CO using a HP6890 gas chromatograph equipped with dual columns (molecular sieve and porapak) and thermal conductivity detectors.

Results

Grand Sierra Pontoon Houseboat #112

During the afternoon of January 24, 2001, CO samples were collected on a Grand Sierra pontoon houseboat with the specifications listed below. During this evaluation, the gasoline generator operated alone for approximately 25 minutes. Subsequently, the gasoline motors and generator were operated together for approximately 16 minutes. The test was conducted just prior to a storm moving through the area; therefore, the test was conducted under windy conditions.

Engines: One outboard marine corporation (OMC) 70 HP Johnson motor, and one Evinrude 70 HP engine
Generator: 8.5 Kw Westerbeke, 4 cylinder, 1.0 liter gasoline generator
Exhaust Configuration: Generator exhaust discharged out to the side of the houseboat.
Wind speed above deck: air speed readings ranged between 560 - 1580 feet per minute

Area around exhaust and off back of houseboat

Figure 2 shows a portion of the back deck of the Grand Sierra pontoon houseboat, and illustrates the generator exhaust discharging out the side. Figure 3 shows a close-up view of the exhaust discharge, and warning label above the discharge.

One evacuated glass container sample was collected in the area near the generator exhaust discharge. This sample indicated a CO concentration of 463 ppm. The emissions analyzer sampling probe was placed near the generator exhaust discharge of the houseboat. A total of 17 readings were obtained (over a 19 minute period) when only the generator was in operation. The recorded CO concentration ranged from 0.01% (100 ppm) to 0.22 % (2,200 ppm) with an average of 0.08 % (800 ppm) while the generator was in operation. A total of 12 CO concentration readings were obtained near the generator exhaust discharge when the generator and engines were both in operation. These CO concentrations ranged from 0.0 % (0 ppm) to 0.18% (1800 ppm) with an average of 0.05 % (500 ppm).

A detector tube sample collected in the area around the generator exhaust indicated CO concentration greater than 700 ppm while the generator was in operation.

Area Above Swim Deck on Back of Boat

The prevailing wind direction was moving from the front of the houseboat toward the back of the of the houseboat. Therefore, the wind was moving away from the back deck under windy conditions (a storm was moving into the area during the evaluation). Table 1 lists the CO monitor results obtained on the back of the Grand Sierra pontoon houseboat, with the generator and motors operating.

Table 1. Sample locations and CO results on the Grand Sierra houseboat.

Location	**CO average (ppm)**	**CO peak (ppm)**
Only Gasoline Generator Running (ran for approximately 25 minutes without motors operating)		
Right side of swim platform (when on boat and facing the water) at floor level	118	306
Left side of swim platform (when on boat and facing the water) at floor level	6	23
On gate going to swim platform on back deck	0.6	2
On the right side of the rear portion of the back deck (at floor level)	0.8	12
On stairs going up to top deck (at breathing zone height)	10	34
On the top deck of boat	0.9	2
On patio door on back deck	No CO Detected	
Gasoline Generator and Gasoline Powered Outboard Motors Running (ran together for approximately 16 minutes)		
Right side of swim platform (when on boat and facing the water) at floor level	147	333
Left side of swim platform (when on boat and facing the water) at floor level	123	260
On gate going to swim platform on back deck	1.3	5
On the right side of the rear portion of the back deck (at floor level)	1.3	3

Gasoline Generator and Gasoline Powered Outboard Motors Running (ran together for approximately 16 minutes)		
On stairs going up to top deck (at breathing zone height)	14	24
On the top deck of boat	1.2	3
On patio door on back deck	0.14	2

Crown Ship Pontoon Houseoat

During the morning on January 25, 2001, CO samples were collected on a Crown Ship pontoon houseboat with the specifications listed below. During this evaluation, the gasoline generator operated alone for approximately 33 minutes. Subsequently, the gasoline motors and generator were operated together for approximately 25 minutes.

Engines: Two Outboard Johnson Motors (one 70 HP and one 60 HP)
Generator: 8.5 Kw Westerbeke, 1 liter gasoline generator
Exhaust Configuration: Generator exhaust out side of the boat.
Air speed off back deck: air speed readings ranged between 10-39 feet per minute

Area around exhaust off back of houseboat

An evacuated glass container sample was collected in the area near the generator exhaust discharge at the back of the houseboat when the generator was in operation (motors were not operating). The sample was collected upstream of the wind movement near the exhaust and indicated a CO concentration of 5 ppm.

The emissions analyzer sampling probe was placed near the generator exhaust discharge. A total of 14 readings were obtained (over a 19 minute period) when only the generator was in operation. The recorded CO concentration ranged from 0.01% (100 ppm) to 0.47 % (4,700 ppm) with an average of 0.22 % (2,200 ppm). A total of 17 CO concentration readings were obtained near the generator exhaust discharge when the generator and engines were both in operation. These CO concentrations ranged from 0.00 % (0 ppm) to 0.31 % (3,100 ppm) with an average of 0.11 % (1,100 ppm). During brief periods, when the generator was in operation and CO concentrations were high, the emissions analyzer would also indicate that the area directly around the exhaust discharge was oxygen deficient (< 19.5 % O_2).

Area Above Swim Deck on Back of Boat

The prevailing wind direction was toward the front left corner of the rear deck (when on back of boat and facing the water) and flowing across the back deck to the back right corner. The generator

exhaust was discharging out the right side of the houseboat (See Figure 4). Figure 5 shows a close-up view of the exhaust discharge. Table 2 lists the CO monitor results.

Table 2. Sample locations and CO results on the Crown Ship Pontoon Houseboat.

Location	CO average (ppm)	CO peak (ppm)
Only Generator Running (ran for approximately 33 minutes without motors operating)		
Left side on rear portion of back deck on rail	23	73
Left side of the back deck (at floor level)	50	158
Right side of back deck (on generator box)	65	198
Center of back deck (on left portion of generator box)	43	140
Right side on rear portion of back deck	40	150
On the top deck of boat	5	29
Inside the boat (patio door open)	14	56
Under front of boat between the pontoons	120	286
Generator and Motors Running (ran together for approximately 25 minutes)		
Left side on rear portion of back deck on rail	24	56
Left side of the back deck (at floor level)	102	254
Right side of back deck (on generator box)	67	178
Center of back deck (on left portion of generator box)	68	323
Right side on rear portion of back deck	31	96
On the top deck of boat	6	18
Inside the boat (patio door open)	8	21
Under front of boat between the pontoons	23	115

Summit Ship Pontoon Houseboat

During the mid-morning on January 25, 2001, CO samples were collected on a Summit Ship pontoon houseboat with the specifications listed below. This houseboat was equipped with a gasoline generator and motors. The generator was operated for approximately 29 minutes. Subsequently, the motors and generator were operated simultaneously for approximately 21 minutes.

Engines: Two 60 HP outboard Evinrude engines
Generator: 8.5 Kw Westerbeke, 1.0 liter - 4 cylinder gasoline generator
Exhaust Configuration: Generator exhausted out the side of the boat.
Air speed on left side of back deck: air speed readings ranged between 294 - 540 feet per minute on the back deck
Air speed on center of back deck: air speed readings ranged between 0 - 13 feet per minute

Area around exhaust off back of houseboat and beneath swim deck

Two evacuated glass container samples collected up-wind of the generator exhaust discharge did not detect CO. The exhaust discharge was located on the side of the boat in an area that could not be easily accessed. Therefore, an evacuated container sample could not be collected close the generator exhaust discharge. Detector tube samples could be collected near the exhaust discharge. Two detector tubes collected close to the generator exhaust indicated CO concentrations of approximately 3,000 ppm. An evacuated container sample was collected off the back of the boat when the generator and engines were operating simultaneously. This sample indicated a CO concentration of 253 ppm. See Figure 6 for exhaust discharge and back of Summit Ship pontoon houseboat.

The emissions analyzer sampling probe was placed in the area directly near the generator exhaust discharge. A total of 10 readings were obtained when the generator was in operation, exclusively. The recorded CO concentration (obtained directly near the exhaust discharge) ranged from 0.14 % (1,400 ppm) to 0.42 % (4,200 ppm) with an average of 0.33 % (3,300 ppm). A total of 15 readings were obtained when the generator and motors were in operation. The recorded CO concentration (obtained directly near the exhaust discharge) ranged from 0.19 % (1,900 ppm) to 0.71 % (7,100 ppm) with an average of 0.41 % (4,100 ppm). During brief periods, when the CO concentrations were high, the emissions analyzer would also indicate that the area directly around the exhaust discharge was oxygen deficient (< 19.5 % O_2).

Area Above Swim Deck on Back of Boat

The wind velocity ranged between 294 - 540 fpm on the left side back deck of the houseboat (the side the generator exhaust is located on). The prevailing wind direction was from the front of the boat toward the back of the boat and flowing away from the back deck. Table 3 list the CO monitor results.

Table 3. CO results on the Summit Ship Pontoon Houseboat.

Location	CO average (ppm)	CO peak (ppm)
Only Generator Running (ran for approximately 29 minutes without motors operating)		
On patio door	3	13
Left side of the back deck (on generator box)	17	166
Right side of back deck on gate (near stairs that lead down to water)	3.5	16
Center of back deck	11	45
Right side on rear portion of back deck (on rail)	0.9	3
On the top deck of boat	1	2
Inside the boat (patio door open)	1.8	2
Under front of boat between the pontoons	1	4
Generator and Motors Running (ran together for approximately 21 minutes)		
On patio door	5	48
Left side of the back deck (on generator box)	12	61
Right side of back deck on gate (near stairs that lead down to water)	10	22
Center of back deck	46	106
Right side on rear portion of back deck (on rail)	0.7	1
On the top deck of boat	0.9	1
Inside the boat (patio door open)	1.8	2
Under front of boat between the pontoons	0.3	1

Grand Sierra Pontoon Houseboat #112

During the early afternoon of January 25, 2001, CO samples were collected again on the Grand Sierra pontoon houseboat with the specifications listed below. The test on this houseboat were repeated because of the environmental conditions (a storm was moving into the area) under which the first test was conducted. During this evaluation, the gasoline generator operated alone for approximately 32 minutes. Subsequently, the gasoline motors and generator were operated together for approximately 23 minutes.

Engines: One outboard marine corporation (OMC) 70 HP Johnson motor, and one Evinrude 70 HP engine
Generator: 8.5 Kw Westerbeke, 4 cylinder, 1.0 liter gasoline generator
Exhaust Configuration: Generator exhaust discharged out to the side of the houseboat.
Wind speed above deck: air speed readings ranged between 390 - 660 feet per minute

Area around exhaust and off back of houseboat

Figure 2 shows a portion of the back deck of the Grand Sierra pontoon houseboat, and illustrates the generator exhaust discharging out the side. Figure 3 shows a close-up view of the exhaust discharge, and warning label above the discharge, on the Grand Sierra Houseboat.

One evacuated glass container sample was collected in the area near the generator exhaust discharge. This sample indicated a CO concentration of 224 ppm. Two additional evacuated container samples were collected while the generator and motors were in operation. One of these samples was collected above the stairs (the stairs are located on the opposite side of the back deck from the generator exhaust) that lead down to the water. This sample indicated a CO concentration of 17 ppm. The other evacuated container sample was collected off the back of the swim platform (on the right side when on the back of the boat and facing the water). This sample indicated a CO concentration of 147 ppm.

The emissions analyzer sampling probe was placed in the area directly near the generator exhaust discharge of the houseboat. A total of 15 readings were obtained (over a 20 minute period) when only the generator was in operation. The recorded CO concentration ranged from 0.02% (200 ppm) to 0.21 % (2,100 ppm) with an average of 0.08 % (800 ppm). A total of 13 CO concentration readings were obtained near the generator exhaust discharge when the generator and engines were both in operation. These CO concentrations ranged from 0.02 % (200 ppm) to 0.52% (5,200 ppm) with an average of 0.14 % (1,400 ppm).

A detector tube sample collected in the area directly near the generator exhaust indicated CO concentration of 4,000 ppm while the generator was in operation, exclusively.

Area Above Swim Deck on Back of Boat

The prevailing wind direction was moving from the front of the houseboat toward the back of the of the houseboat. Therefore, the wind was moving away from the back deck. Table 4 lists the CO monitor results obtained on the back of the Grand Sierra pontoon houseboat, with the generator and motors operating.

Table 4. Sample locations and CO results on the Grand Sierra houseboat.

Location	CO average (ppm)	CO peak (ppm)
Only Gasoline Generator Running (ran for approximately 32 minutes without motors operating)		
Right side of swim platform (when on boat and facing the water) at floor level	95	363
On the left side of the rear portion of the back deck (on rail)	0.2	1
On the right side of the rear portion of the back deck (on rail)	3	3
On stairs going up to top deck (at breathing zone height)	5	19
On the top deck of boat	0.5	11
On patio door on back deck	0.7	2
Inside boat (back door open)	0.8	1
In front of boat between the pontoons	0.15	2
Gasoline Generator and Gasoline Powered Outboard Motors Running (ran together for approximately 23 minutes)		
Right side of swim platform (when on boat and facing the water) at floor level	130	212
On the left side of the rear portion of the back deck (on rail)	0.02	1
On the right side of the rear portion of the back deck (on rail)	3	3
On stairs going up to top deck (at breathing zone height)	5	27
On the top deck of boat	0.13	3
On patio door on back deck	1.3	3
Inside boat (back door open)	0.9	1
In front of boat between the pontoons	No CO Detected	

Discussion and Recommendations

The Seven Crown Resorts houseboats evaluated at Echo Bay Marina were designed as pontoon boats with the generator exhaust discharging out to the side. The back of the houseboats did not have slides, and the stairs leading down to the water were located on the opposite side of the boat away from the generator exhaust. Warning CO labels were located on the back of the boat and directly above the generator exhaust discharge (see Figures 3, 5, and 6). These design features help deter individuals from spending time directly near the generator exhaust discharge area. During our evaluation at Echo Bay Marina the prevailing wind was moving the exhaust gases away from the back of the houseboats and not toward the back decks. Therefore, no extremely high CO concentrations (CO concentrations above the NIOSH IDLH value of 1,200 ppm[4]) were measured on the back of the houseboats. IDLH environments were measured with detector tubes and the emissions analyzer directly near the generator exhaust discharge. Therefore, the possibility of high CO concentrations may exist under environmental conditions that would carry the exhaust gases toward the back of the houseboat. A previous study has documented that the area around the back deck of houseboats can be hazardous under certain environmental conditions (i.e., lack of air movement) when the generator or motors are in operation.[1] Individuals swimming or working in the area directly near the generator exhaust (with the gasoline generator in operation) could be exposed to extremely high CO concentrations resulting in CO poisoning or death within a short period of time.

This evaluation was performed in January which is not in the prime operating season for houseboats. Activities at the dock were slow, due to the low number of houseboat rentals. Therefore, personal sampling was not conducted. However, general recommendations are provided to help control potential worker CO exposures. In addition, recommendations are provided to reduce the potential for CO exposure around the generator exhaust and back deck on houseboats.

1) Public education efforts must immediately inform and warn all individuals (including boat owners, renters, and dock workers) potentially exposed to these CO hazards. Public education programs should continue until engineering control solutions that eliminate the problem are in place. The pontoon boats evaluated during this study have a space between the pontoons in which individuals may enter and swim. Individuals should be instructed that this is not a safe practice and under certain environmental conditions (with the generator in operation) CO concentrations could potentially be elevated in this area. This practice should be prohibited.

An effort is being made to inform manufacturers of houseboats about the environmental data that has been collected, and the related design concerns. On September 1, 2000, the National Park Service (NPS) sent each of these manufacturers a letter informing them of the numerous deaths that may be attributed to CO poisoning from houseboat generator and/or engine exhaust. In these letters, the Park Service specifically pointed out that most of the deaths occurred when the victim was either on the back deck or in the water near or under the swim platform. In addition to this effort, the initial NIOSH letter describing the first evaluation of CO on houseboats at Lake Powell was also sent to 58 houseboat

manufacturers.[1] This effort should be continued until all manufacturers are aware of the problem and solutions are formulated to redesign and correct the exhaust configuration. This should also include the redesigning of side-exhausting boats to help eliminate CO problems when boats are tied together, or when someone is in the area where the exhaust gases are expelled from the boat. An investigation was conducted at Lake Powell on a houseboat with a generator exhaust design that discharged the exhaust gases through a stack well above the upper deck of the houseboat away from occupied areas. This study indicates that the exhaust gases can diffuse and dissipate into the atmosphere to relatively safe levels, prior to reaching occupants on or near the houseboat.[5]

2) Previous investigations have indicated that boat mechanics can be exposed to high concentrations of CO.[1,2] Therefore, the feasibility and effectiveness of engineering controls should be investigated to help control CO exposures to boat maintenance mechanics. If repairs are conducted outside and at the boat dock (where electric power is easily available), the use of a high volume fan or other air-moving device may be effective in preventing worker short-term high-level exposures to CO. Research into potential engineering controls needs to be accomplished to make sure that the workers' are protected from CO and that any exhaust from these controls is discharged into a well-ventilated area that is not occupied; therefore, eliminating the possibility of individuals breathing the exhaust from the control device.

3) Training about the severity of CO hazards in boating should be developed for marina personnel, EMS providers, and hospital emergency department staff so that symptoms experienced by either employees or other boat operators might be more easily associated with exposures. This training should include both environmental data, as well as information about the number and circumstances of CO poisonings on the lake.

4) The U.S. NPS has launched an awareness program to inform boaters on Lake Powell about boat-related CO hazards. This program included press releases, flyers distributed to boat and dock-space renters, letters to boat owners, and verbal information included in the boat check-out training provided for users of concessionaire rental boats. Similar information should be distributed to boat and dock-space renters at Echo-Bay Marina. Verbal information should be included in the boat check-out training provided for users of rental boats. Training about the specific boat-related CO hazards provided to houseboat renters, should include specific information about the circumstances and number of poisonings and deaths that have been documented in previous CO evaluations.[1] The training should include anecdotal information about deaths and near misses, and should specifically target warnings against entering areas near the gasoline generator exhaust or immediately behind the back deck that may contain a lethal atmosphere.

Thank you for your cooperation with this investigation, and for providing important data related to this serious issue. Please contact me at (513) 841-4387 if you have any questions regarding this evaluation. Jane McCammon at (303) 236-6233 is an additional contact who can answer any questions or concerns you may have regarding CO fatalities and poisoning incident reports on houseboats.

Sincerely,

Ronald M. Hall, M.S.
Industrial Hygienist
Industrial Hygiene Section
Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

cc: Dick Powell, USNPS Safety Director
Lloyd Olson, USNPS
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Mike Kaas, USDOI, Office of Managing Risk and Public Safety
William Dickenson, Park Superintendent, Lake Mead National Recreation Area
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Allison Deeb, Safety Manager, Lake Mead National Recreation Area
Phillip Cappel, USCG
Tim Radtke, Industrial Hygienist, Department of Interior
Dr. Robert Baron
Char O'Bergh, NPS Glen Canyon National Recreation Area

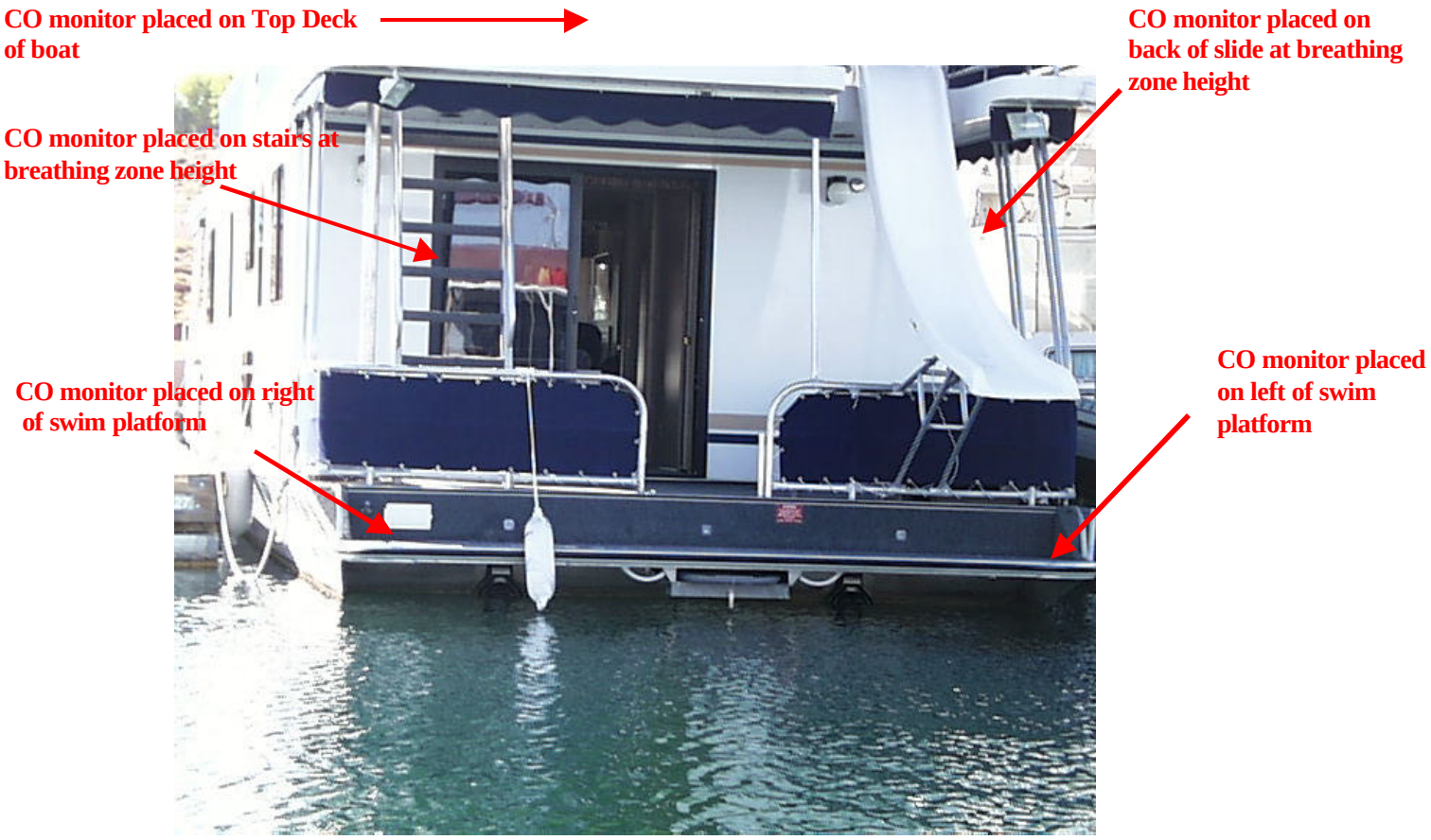

Figure 1. Swim platform and back deck of a houseboat with general CO sample locations. *[This figure indicates the general locations of CO monitors during all houseboat evaluations and is not a representation of a typical houseboat at Echo Bay Marina]*

Figure 2. Back View of the Grand Sierra Pontoon Houseboat.

Figure 3. Generator exhaust discharge on the Grand Sierra Pontoon Houseboat.

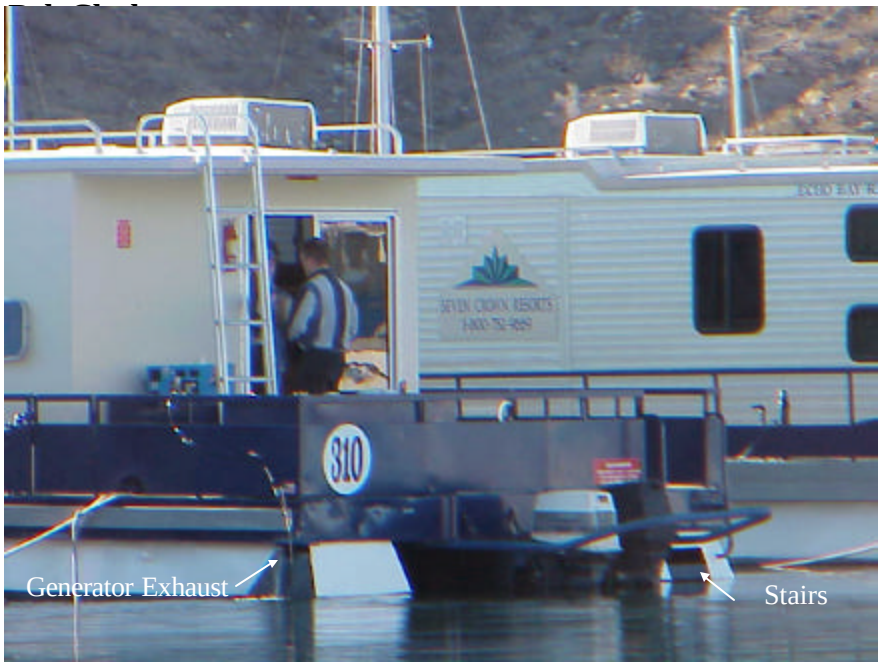

Figure 4. Back view of the Crown Ship Pontoon Houseboat.

Figure 5. Close-up view of the exhaust discharge on the Crown Ship Pontoon Houseboat.

Figure 6. Back deck of Summit Pontoon Houseboat.

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3. Hall, RH,[2000]. Letter of December 18, 2000, from R. Hall, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services, to Dr. Rice Leach, Commissioner, Cabinet for Health Services, Commonwealth of Kentucky, Department for Public Health, Frankfort, Kentucky.

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Attachment 1
Health Effects of Exposure to Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline or propane fuel. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, or nausea. Symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. If the exposure level is high, loss of consciousness may occur without other symptoms. Coma or death may occur if high exposures continue.[1-6] The display of symptoms varies widely from individual to individual, and may occur sooner in susceptible individuals such as young or aged people, people with preexisting lung or heart disease, or those living at high altitudes.

Exposure to CO limits the ability of the blood to carry oxygen to the tissues by binding with the hemoglobin to form carboxyhemoglobin (COHb). Blood has an estimated 210-250 times greater affinity for CO than oxygen, thus the presence of CO in the blood can interfere with oxygen uptake and delivery to the body. Once absorbed into the bloodstream, the half-life of bloodborne CO at sea level and standard pressure is approximately five hours. This means that an initial COHb level of 10% could be expected to drop to 5% in five hours, and then 2.5% in another five hours. If oxygen is administered to the exposed person, as happens in emergency treatment, the COHb concentration drops more quickly. Once exposed, the body compensates for the reduced bloodborne oxygen by increasing cardiac output, thereby increasing blood flow to specific oxygen-demanding organs such as the brain and heart. This ability may be limited by preexisting heart or lung diseases that inhibit increased cardiac output.

Altitude effects the toxicity of CO. With 50 ppm CO in the air, the COHb level in the blood is approximately 1% higher at an altitude of 4,000 feet than at sea level. This occurs because the partial pressure of oxygen (the gas pressure causing the oxygen to pass into the blood) at higher altitudes is less than the partial pressure of CO. Furthermore, the effects of CO poisoning at higher altitudes are more pronounced. For example, at an altitude of 14,000 feet, a 3% COHb level in the blood has the same effect as a 20% COHb at sea level.[7]

References

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Attachment 2
Evaluation Criteria

Although NIOSH typically focuses on occupational safety and health issues, the Institute is a public health agency, and cannot ignore the overlapping exposure concerns in this type of setting. Lake Mead employees should be in a state of health typical of any industrial worker. Thus, occupational criteria for CO exposure are applicable to that group. The general boating public, however, may range from infant to aged, be in various states of health and susceptibility, and be functioning at a higher rate of metabolism because of increased physical activity. The effects of CO are more pronounced in a shorter time if the person is physically active, very young, very old, or has preexisting health conditions such as lung or heart disease. Persons at extremes of age and persons with underlying health conditions may have marked symptoms and may suffer serious complications at lower levels of carboxyhemoglobin.[(1)] The occupational exposure limits noted below should not be used for interpreting general population exposures because they would not provide the same degree of protection they do for the healthy worker population.

Occupational Exposure Criteria. As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, or a pre-existing medical condition. In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[(2)] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®), [(3)] (3) the legal requirements of the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs),[(4)] and (4) the American Society of Heating, Refrigerating, and Air-ConditioningEngineers (ASHRAE) Standard for ventilation for acceptable indoor air quality.[(5)] Employers are encouraged to follow the more protective criterion listed.

A TWA exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

The NIOSH REL for CO is 35 ppm for full shift TWA exposure, with a ceiling limit of 200 ppm which should never be exceeded.[6,7] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with COHb levels in excess of 5%.[1] NIOSH has established the immediately dangerous to life and health (IDLH) value for CO as 1,200 ppm.[8] An IDLH value is defined as a concentration at which an immediate or delayed threat to life exists or that would interfere with an individual's ability to escape unaided from a space.

The ACGIH recommends an eight-hour TWA TLV of 25 ppm based upon limiting shifts in COHb levels to less than 3.5%, thus minimizing adverse neurobehavioral changes such as headache, dizziness, etc, and to maintain cardiovascular exercise capacity.[9] ACGIH also recommends that exposures never exceed 5 times the TLV (125 ppm).

The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.[10]

Health Criteria Relevant to the General Public.
The US EPA has promulgated a National Ambient Air Quality Standard (NAAQS) for CO. This standard requires that ambient air contain no more than 9 ppm CO for an 8-hour TWA, and 35 ppm for a one-hour average.[11] The NAAQs for CO was established to protect "the most sensitive members of the general population" by maintaining increases in carboxyhemoglobin to less than 2.1%.

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bcc:
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HETA 2001-0100 (Close-out)
SIC Code: 4493 Establishments primarily engaged in operating marinas and which perform incidental boat repair
Key Words: Houseboats, Carbon Monoxide, Lake Mead, and Gasoline Generators
Toxicity Det: High concentrations of Carbon Monoxide directly near generator exhaust